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An Overview of Human Figure Modeling for Army Aviation Systems

by Jamison S. Hicks, David B. Durbin, and Richard W. Kozycki

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14. ABSTRACT
The U.S. Army Research Laboratory, Human Research and Engineering Directorate (ARL-HRED) conducts human figure modeling to design and test Army systems. The modeling has been used to assess and improve the ergonomic design and usability of all modernized Army Aviation systems, as well as to reduce analysis and development timelines. ARL-HRED has also developed a digital library of Army Aviation aircraft and equipment to assess whether or not the aircraft and equipment meet human factors engineering design standards. The modeling conducted by ARL-HRED has resulted in numerous system design improvements to meet the human factors engineering design standards. Human figure modeling will continue to play an increasingly important role in the future, as Army Aviation program managers work to develop effective systems, minimize design costs, and shorten design, development, and production timelines.

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1. Introduction

1.1 Purpose

The U.S. Army Research Laboratory, Human Research and Engineering Directorate (ARL-HRED) conducts human figure modeling to design and test U.S. Army systems. The modeling has been used to assess and improve the systems efficiency, usability, and overall ergonomic design. This report summarizes how human figure modeling has been used to develop and test Army Aviation systems. The Aviation systems were the UH-60M Blackhawk, CH-47D Chinook, Armed Reconnaissance Helicopter (ARH), RAH-66 Comanche, Army Airborne Command and Control System (A2C2S), Air Warrior, Advanced Threat Infrared Countermeasure System (ATIRCM), and Common Missile Warning System (CMWS) for the AH-64D.

1.2 Modeling and Simulation

Modeling and simulation (M&S) play an important role in the engineering development of modern military systems and will play an even greater role in the future. The use of human factors engineering (HFE) M&S techniques allows scientists, engineers, and program managers to assess the accommodation of the intended user population by the system design early and continuously throughout the system lifecycle. This can help to reduce the time and costs required for successful acquisition of military systems, and help reduce the risk of not meeting requirements for human system integration (HSI). M&S is used to assess a variety of system requirements including design, performance, risk, and cost. In the case of HFE, M&S is used to assess ergonomic design requirements, mental and physical workload, manpower requirements, and other areas related to HSI.

1.3 Human Figure Modeling

As part of the M&S process, ARL-HRED uses the Jack[*] human figure modeling software to assess the ergonomic design of military systems. Jack is an interactive tool for modeling, manipulating, and analyzing human and other 3-dimensional (3-D) articulated geometric figures (Badler, Phillips, and Webber, 1993). The software also contains a utility for importing anthropometric data that can be used to build and size the human figure models. This allows the human factors analyst to develop the models to represent a specific user population for whom the equipment is targeted.

[*]Jack is a registered trademark of Siemens.

Computer-based graphical human figure models have been used to perform ergonomic analyses of workplace designs since the late 1960s (Das and Sengupta, 1995). This method has gained widespread acceptance over the past two decades, as designers have migrated from traditional paper drafting methods to the use of computer-aided design (CAD) software. These human figure modeling programs have proven to be an effective tool for evaluating the physical interaction between the human and the equipment.

2. Method

2.1 Model Development

A typical human figure modeling analysis consists of several components that are integrated into the 3-D graphical modeling environment. These components include data such as the 3-D surface geometrical representation of the system to be analyzed; human figure models and associated anthropometry data for the target population to be accommodated; clothing and equipment models; posture data; and possibly motion capture data, as well. There are several ways to obtain and input data for simulation and modeling purposes in the Jack software environment. For example, the model of the system to be analyzed can be developed through the use of CAD files obtained from the system developer and imported into Jack, or, if CAD files do not exist or cannot be obtained, the surface geometry of the system can be digitized and also imported. Jack also contains some basic model building utilities that allow the user to work with dimensional data to construct a model of the system design. After the CAD files are generated in the Jack software environment, the human figure models are developed using anthropometry data, which capture the target user population.

Some human figure models that lie on a statistical boundary representation of a target population are shown in figure 1. In the past, uniform body dimensions or univariate models, such as 5th percentile female and 95th percentile male dimensions, were specified to assess most of the equipment designs. For Army Aviation systems, these dimensions are derived from the U.S. Army 1988 Anthropometric Survey (Gordon, Bradtmiller, Churchhill, Clauser, McConville, Tebbetts, and Walker, 1989). However, for design analyses that are multivariate in nature, the use of uniform body dimensions, such as 5th through 95^{th}, may result in designs that actually accommodate far less than 90% that would seem to be implied (Bittner, 1974). For this reason, a multivariate statistical approach can be used to generate boundary forms representing the target population. These boundary forms represent “worst case” extremes of body size and body proportions that must be accommodated in order to capture the desired percentage of users. One such technique, the Principal Components Analysis (PCA) method, can be used to identify important “large-small” body dimension combinations. PCA reduces the dimensionality of the accommodation envelope from n-space (where n is the number of body dimensions that are critical for the design accommodation) to a smaller number of dimensions that account for a large proportion of the original variation by using linear combinations of the original measurements. The resulting combinations provide more realistic human figure models. More information on the PCA method and applications can be found in (Kozycki and Gordon, 2002).

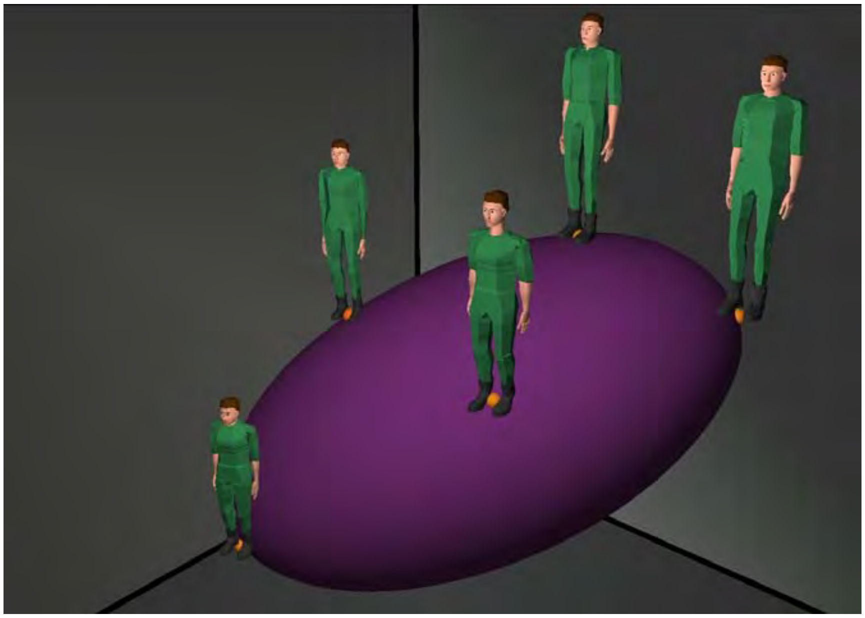

Figure 1. Human figure models.

2.2 Digitized Clothing

Frequently, analyses using human figure models are performed with unclothed body models. While clothing bulk and encumbrances may be safely disregarded for some types of workplace analyses, they are an important factor in applications such as an aircraft crewstation, where space is at a premium (Kozycki, 1998). Helicopter piloting is one example in which clothing and equipment have an impact on operator performance. Figure 2 shows an example of a pilot wearing an over-water mission ensemble. Recent advances in aircraft operational demands and capabilities have necessitated additional protective equipment, resulting in an increasing burden on the aircrew. In addition to the traditional flight gear and life support equipment for altitude, acceleration, and hearing protection, aircrews are now being laden with systems for nuclear, biological, and chemical (NBC) warfare; enhanced acceleration protection; passive anti-drown capability; helmet-mounted electro-optical devices; and laser/flash blindness protection. The current ensemble of protective clothing and equipment is bulky; it also causes rapid build-up of heat stress, limits field of view (FOV), and degrades aviator performance (Wright, Hanson, and Couch, 1996). Over the past several years, ARL-HRED has built a library of digitized Soldier clothing and equipment items, such as helmets, vests, packs and individual Soldier weapons. The models are segmented at the shoulders, elbows, waist, hips, and knees.

Figure 2. Army pilot seated in a helicopter crewstation wearing an over water mission ensemble.

This procedure allows for real-time movement of the human figure when it is fitted with the clothing models, and the clothing can also be scaled to fit a range of body sizes. Figure 3 is an example of digitized human figure models in various clothing and equipment.

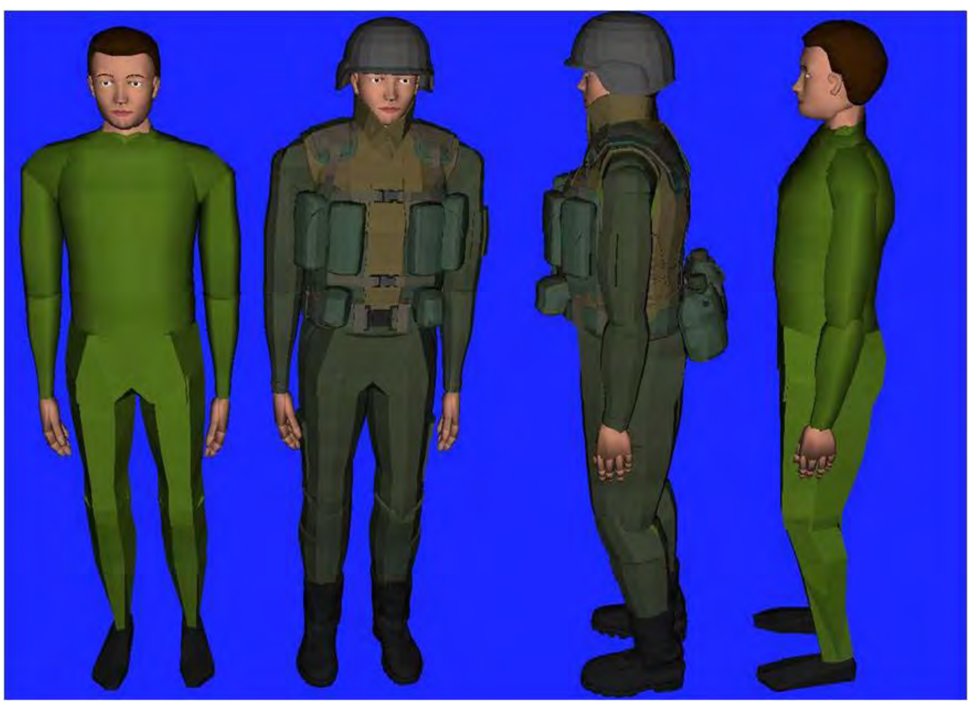

Figure 3. Digitized Soldiers, clothing, and equipment.

2.2.1 Motion Capture and Marker Data

Motion capture technology focuses specifically on capturing complex human motion by using a combined hardware and software environment. The motion capture process is conducted by attaching reflective markers to a human subject. Figure 4 shows a pilot with the reflective markers attached to his equipment and clothing (Kennedy, Durbin, Faughn, Kozycki, and Nebel, 2004). These markers allow cameras to capture the complex movements performed by the subject. Once the motion has been captured, digital traces or paths are generated that can be used to animate digital human figure models for the purpose of analysis, simulation, and training.

Figure 4. Pilot with reflective markers.

A problem with incorporating human motion into a model is that complex human motions that were developed by a programmer or animator for computer-generated figures typically have an unnatural or unrealistic appearance. Motion capture equipment provides the ability to capture the normal human action or activity and view the captured motion from virtually any desired angle. The motion capture data, when combined with human figure modeling, represents the actual posture and procedure used by a human subject performing the task, and not a subjective motion sequence developed by a programmer or animator.

In order to use motion capture data in Jack, human figure models must first be created and sized accurately to reflect each subject's body anthropometry. Once these models are formed, the motion capture data can be imported into the Jack software and used to control the movements of the human figure body segments and reproduce the motions of the subject for whom the motion capture data is collected. In order to develop more realistic models and accurately replicate human motion, motion capture technology must continue to be incorporated into the modeling and simulation techniques performed by human factors engineers.

In order to validate the data collection and modeling, the motion is also recorded on video, and the playback of the motion capture using the Jack figure can be compared to the video footage. Additionally, the figure is built to match the body dimensions of the subjects that participate in the exercise. The construction of the figure must be very precise in order for the motion capture to play back correctly. This requires not only that the anthropometry match the subject, but that the placement of the markers must match, as well.

2.2.2 Equipment Modeling

The Jack software is capable of importing various types of CAD models to develop system and equipment models in the modeling environment. In some cases, the manufacturer's drawings can be used as a direct import into the Jack software for manipulation. However, due to limited software release stipulations and occasional problems with software interpretation, ARL-HRED is making an independent effort to develop a digital library of the primary Army Aviation aircraft and associated equipment models. The development of these models requires precise measurement tools, such as laser scanning equipment or portable Coordinate Measuring Machines (CMM), to collect the surface geometry data. Figure 5 shows an AH-64 Apache tailboom being prepared for digitization.

After the digitization process, the model is developed and checked for accuracy and errors. When the model is complete, articulation of moveable parts—e.g., seats and flight controls—is added so that these components can simulate the movement or adjustment that would be found in the actual equipment. The final product is then available for importation into various modeling environments for manipulation and further analysis. The modeled AH-64 tailboom section is shown in figure 6.

2.3 Model Analysis

The Jack model is used to perform human factors engineering analyses by comparing the generated model information to several different measures. These measures are typically dependent on the specific application, but usually include equipment design criteria (e.g., visual access to displays), human factors engineering standards (e.g., MIL-STD-1472), and subject matter expert (SME) observation. The analyst will use a combination of these criteria to evaluate the model and generate appropriate results.

Figure 5. AH-64 Apache tailboom being digitized.

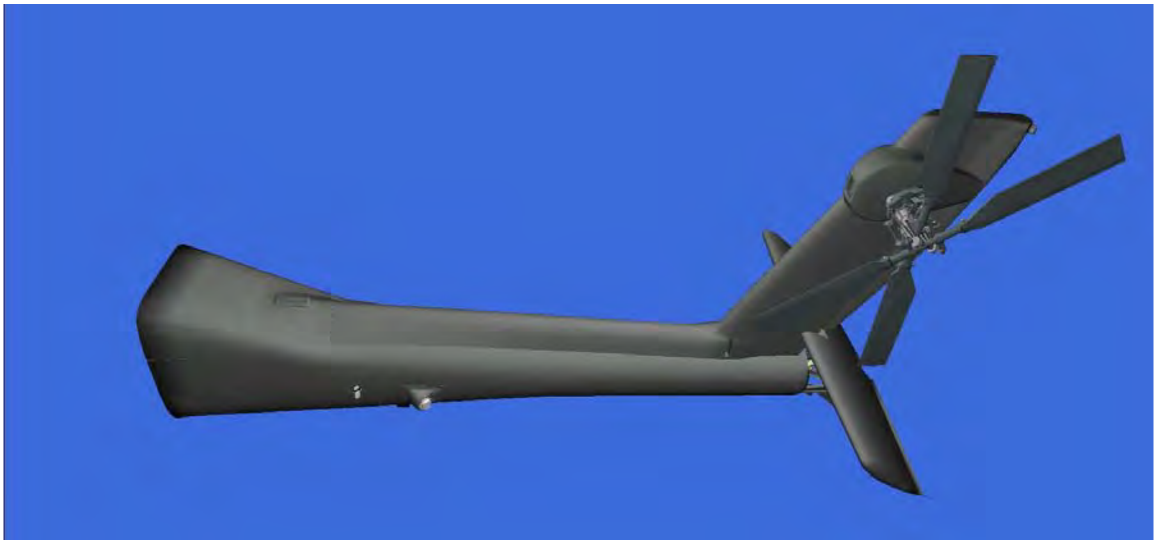

Figure 6. 3-D model of AH-64 Apache tailboom section.

2.4 Limitations of Human-Figure Modeling

As the Jack model is a simplified representation of the human body, there are limitations as to how accurately Jack can dynamically model body movement. Newer technologies are being developed and refined, including 3-D whole body scanning. 3-D whole body scanning is being used to develop higher fidelity human-figure models that can be used for ergonomic analysis.

However, these higher fidelity models present challenges with segmentation and gaps that develop when trying to incorporate body joints and an upper body torso that must bend, twist, and flex.

No single human figure modeling tool can be used to perform all types of anthropometric analyses. There are many different types of human figure modeling software. Some are well suited to perform space reach and vision analyses, while others are used to examine biomechanics or strength issues, for example. Still other human figure modeling software is geared to the analysis of cognitive issues. The analyst must know the limitations of that tool and choose the best one suited for the human performance issues to be examined.

3. Results

3.1 Army Aviation Systems

The Jack modeling software has been used by ARL-HRED in the development and testing of eight Army Aviation systems. The modeling was funded by Aviation program managers, and the results supported analyses by the Army Test and Evaluation Command (ATEC), Training and Doctrine Command (TRADOC) Capabilities Managers (TCM), Aviation and Missile Research, Development and Engineering Center (AMRDEC), Boeing, Bell Helicopter, Sikorsky, BAE Systems, and ARL-HRED. Table 1 lists the Aviation systems for which Jack has been used to assess and improve the ergonomic design and system capabilities.

Table 1. Aviation systems.

System	Evaluation
RAH-66 Comanche	- Ingress/Egress Analysis - Crewstation Design - Rearview Mirror Location - Helmet Integrated Display Sight System (HIDSS) Analysis
UH-60M Blackhawk	- Crewstation Design - Anthropometric Design Analysis
Army Airborne Command and Control System (A2C2S)	- Egress Analysis
Air Warrior	- Anthropometric Design Analysis
Common Missile Warning System (CMWS) for the AH-64D	- AH-64D CMWS Sensor Field of View
Advanced Threat Infrared Countermeasure (ATIRCM)	- Maintenance Analysis
Armed Reconnaissance Helicopter (ARH)	- Transportability Analysis - Anthropometric Design Analysis
CH-47D Chinook	- Anthropometric Design Analysis

3.1.1 RAH-66 Comanche

The RAH-66 Comanche was a tandem-seated configuration reconnaissance and attack helicopter. We used Jack to help conduct crewstation design, assess anthropometric requirements for female and male aviators, evaluate volume of space requirements for pilots wearing the helmet, assess pilot emergency egress (Kennedy, Durbin, Faughn, Kozycki, Nebel, 2004), and determine the optimal location for the rearview mirror based on sightlines available to the pilots seated in the crewstations (figure 7).

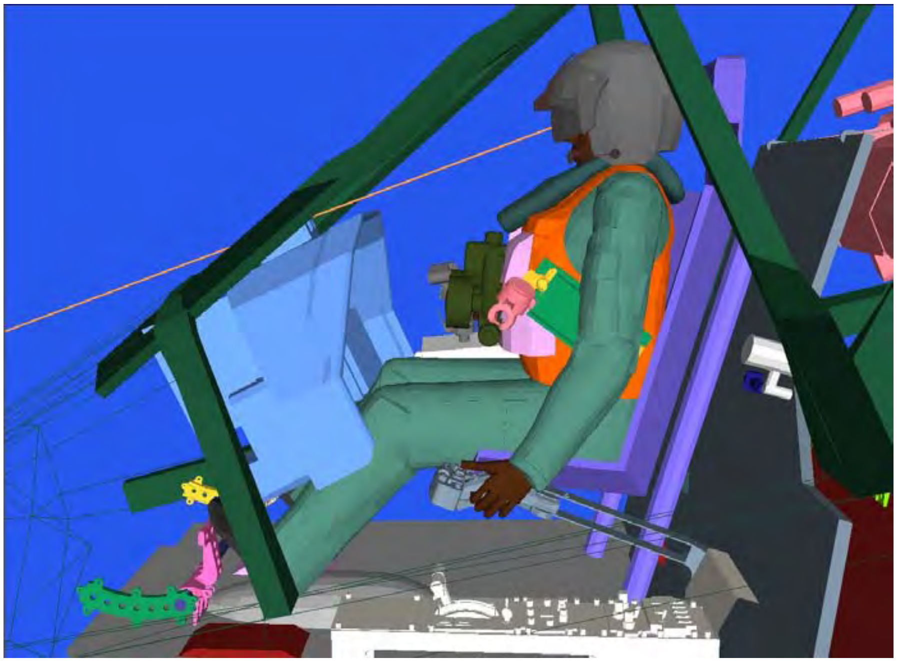

Figure 7. Example of pilot sightlines for crewstation development.

In the early 1990s, the U.S. Army changed its policy to allow women aviators to fly combat missions, which meant that the Comanche helicopter needed to meet crewstation requirements to accommodate female aviators. During this requirement change, new aviation life support equipment (ALSE) was also entering the inventory system. The change in ALSE and the requirement change meant that Army aviators who were significantly larger or smaller than average might not be fully accommodated by the Comanche crewstation. We used Jack to assess whether large males and small female aviators would be accommodated by the Comanche crewstation design while wearing the new ALSE (Kozycki, Gordon, 2002).

Results of the Jack analysis indicated that the crewstation design accommodated most aviators. However, the design did not fully accommodate the target population, especially for both the small female and large male pilots. For example, figure 8 shows a small female unable to reach the engine control levers (ECLs) located on the side console panel. Figure 9 shows a large male with insufficient knee clearance at the lower section of the instrument panel.

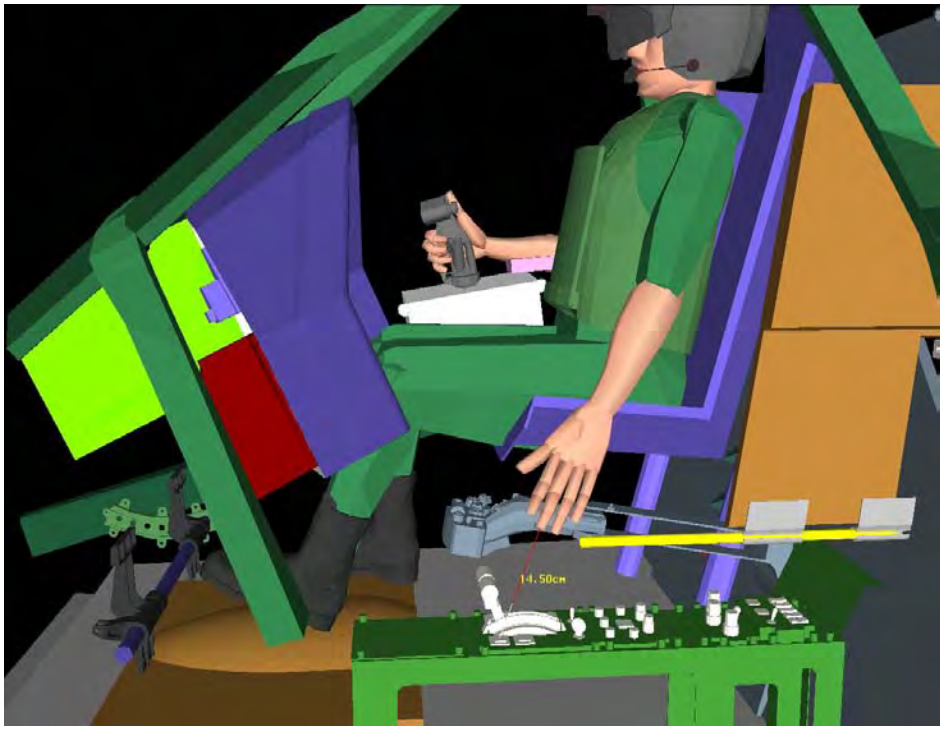

Figure 8. Small female unable to reach ECL.

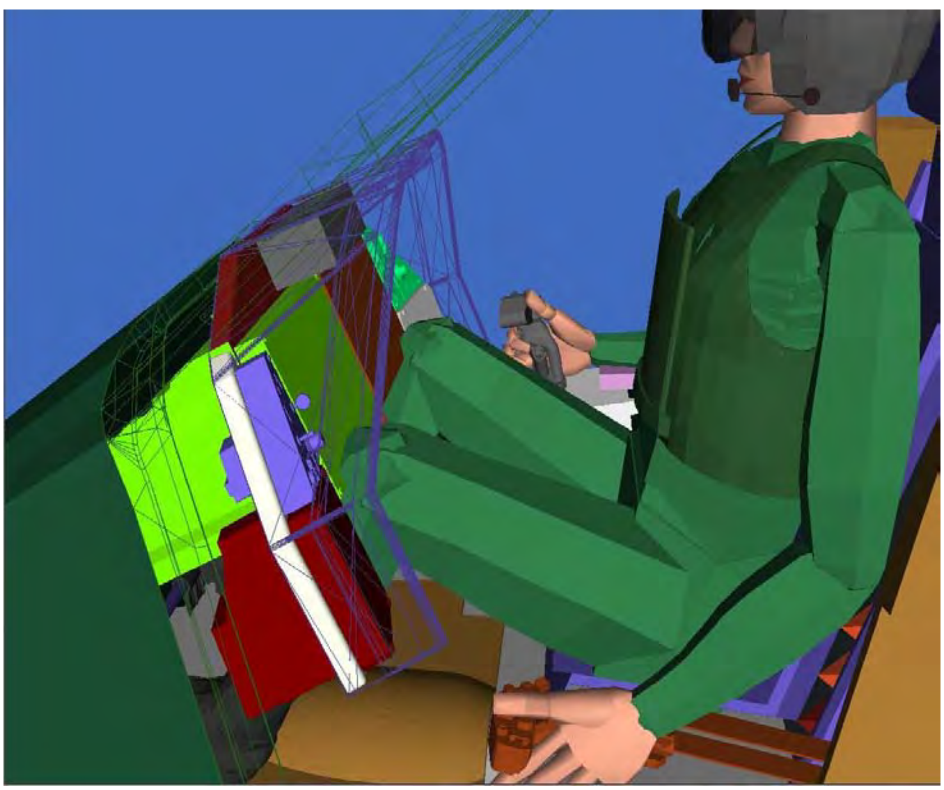

Figure 9. Large male with insufficient knee clearance.

The Jack analysis also identified that the crewstation design did not allow small pilots to reach the pedals and instrument panels. Small females were unable to view the instrument panels when seated, unless they removed their hands from the collective and moved to their left (figure 10).

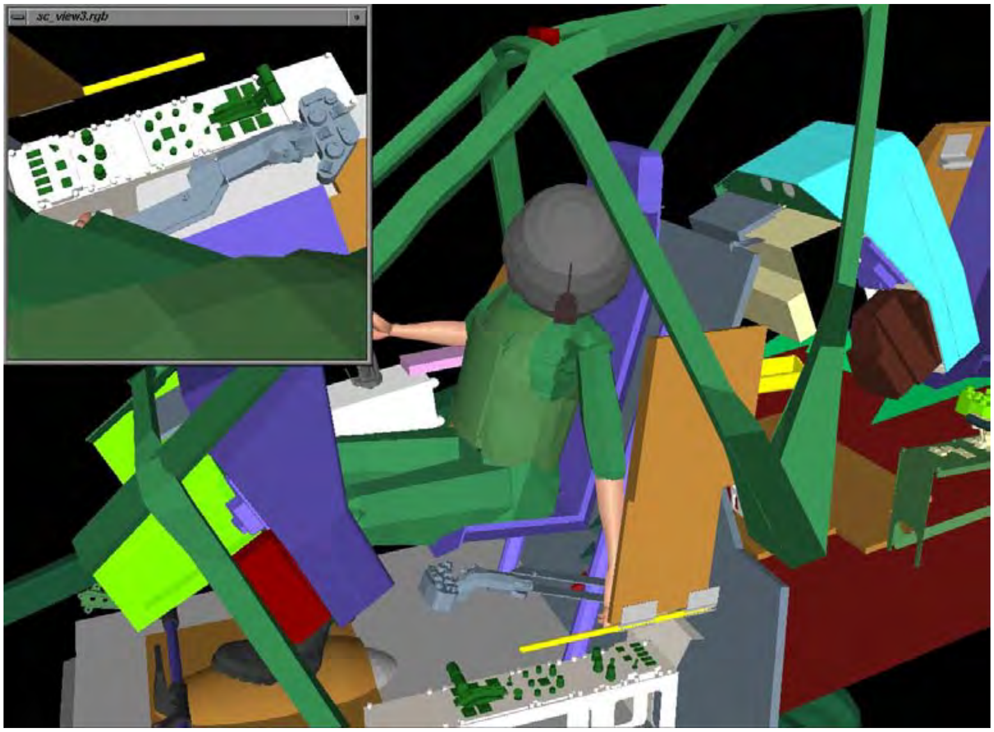

Figure 10. Small female positioned to view the instrument panels.

Results of the Jack analysis led to modifications to the Comanche crewstation to improve physical accommodation for large male and small female aviators. These modifications included canting of the side console panel to improve visual access and reach to the ECLs; improved seat adjustment to allow access to the pedals and front instrument panels for small female aviators; and increased volume of space for large males to improve knee clearance around the lower section of the instrument panel.

The anthropometric and motion capture data collected during the egress testing for RAH-66 Comanche was used to identify potential problem areas during the egress trial exercises. Figure 11 shows a problem with knee clearance for large male pilots that was identified during the egress trials. Modifications to the lower front console panel to improve knee clearance were being implemented prior to program termination.

Figure 11. Pilot knee interference.

Jack was also used to evaluate upper torso and head movement by large males and small females inside the Comanche cockpit while wearing the HGU-56P helmet, which was equipped with the Helmet Integrated Display Sight System (HIDSS). The HIDSS included a helmet-mounted display consisting of a right and a left display, a helmet tracking system, a boresight reticle unit, and associated electronics. The system was cumbersome and inhibited the maneuverability of pilots inside the cockpit. Jack was used to examine the limits of lateral and forward upper-body movements, in combination with rotational head movement, required to produce a helmet strike with the adjacent canopy frame structure or windscreens that made up the Comanche cockpit. A range of 3-D human figure model sizes was incorporated into the modeling application to investigate the limitations. Figure 12 shows a 3-D rendering of the HIDSS.

The HIDSS analysis was conducted for both male and female models in the forward and aft crewstation positions to investigate the helmet strike interference that could occur when using the HIDSS and to identify possible solutions (Kozycki, 2002). As an example from the study, table 2 shows the data results collected from the Jack software that measured the maximum maneuverability by male pilots with 95th, 75th, and 50th percentile seated heights in the forward crewstation position. Figure 13 shows a human model wearing the HGU-56P helmet and HIDSS while seated in the cockpit.

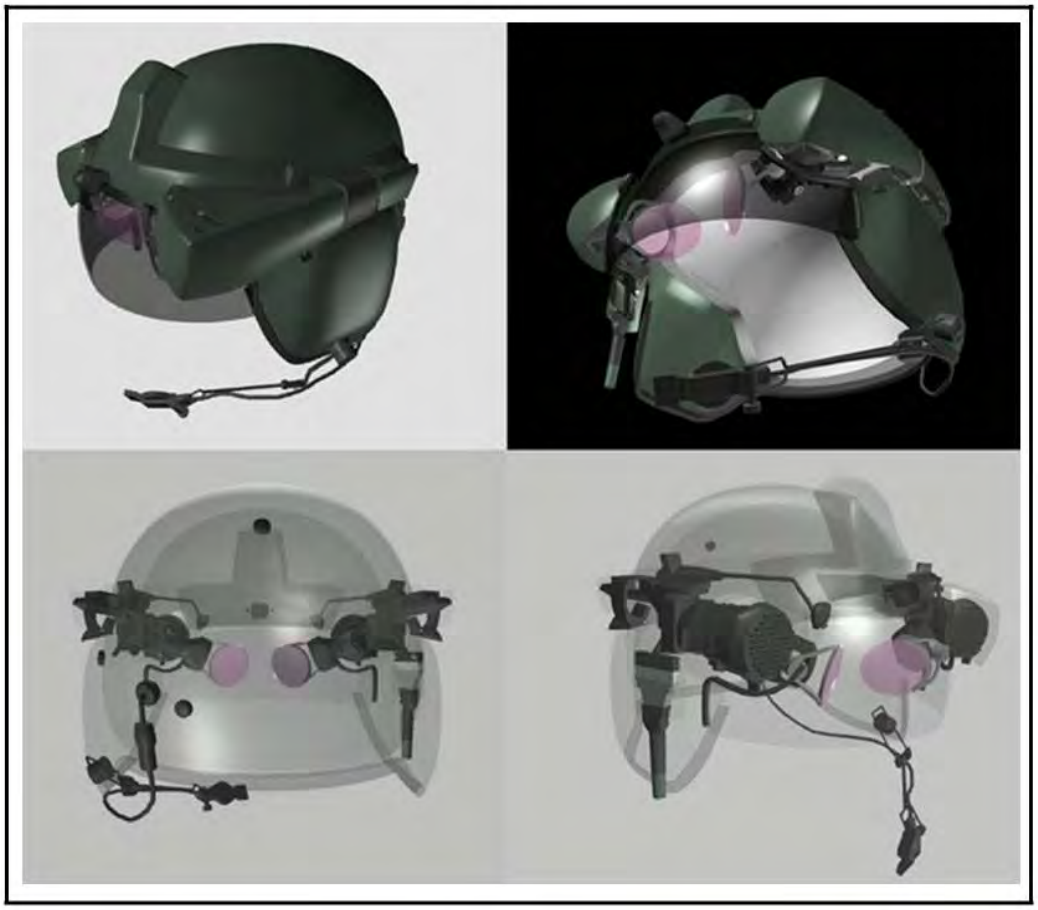

Figure 12. 3-D rendering of the HIDSS.

Table 2. Maximum maneuverability for a range of males in the forward seating position.

Human Figure - Forward	**Male 95th (°)**	**Male 75th (°)**	**Male 50th (°)**
Lateral body lean without rotational head movement	12	14	15
Lateral body lean with 40° rotational head movement	8	10	11
Forward body lean	21	21	22

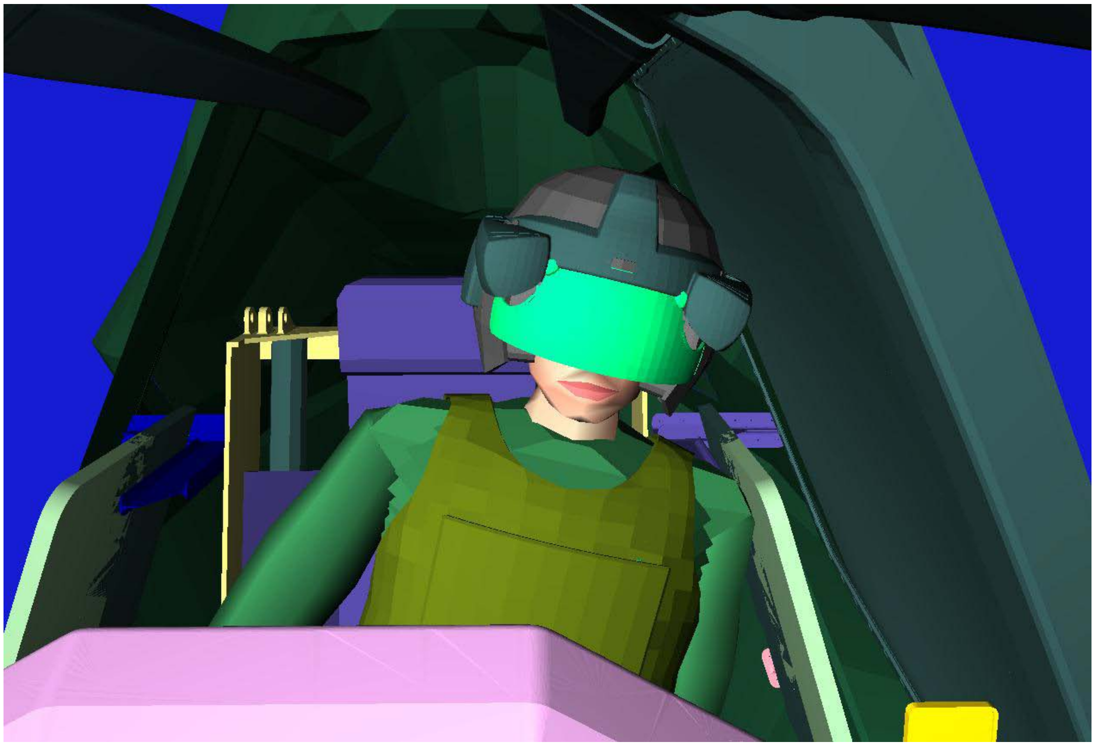

Figure 13. Human model wearing the HGU-56P and the HIDSS.

The figures and tables presented provide both visual and empirical data that illustrated the maximum amount of maneuverability available inside the cockpit when the pilots were wearing the HIDSS. The results of this analysis led to recommendations that included adjusting the pilot seat position to minimize the potential for a helmet strike during missions, as well as changes to training material to advise pilots about the potential for helmet contact with the crewstation canopy.

Jack was used to develop an analysis of rearview mirror placements for the Comanche. The human figure models were placed in the cockpit, and visual angles were generated to provide line of sight lines from the model eyes to the mirrors and then reflected through space. This analysis was used to determine appropriate mirror placement for the Comanche cockpit. Figure 14 shows screenshots generated for the assessment.

Figure 14. Screenshots of the rearview mirror analysis.

3.1.2 UH-60M Blackhawk

Jack was used to assess the anthropometric characteristics of the UH-60M Blackhawk crewstation. The UH-60M is an upgrade from the UH-60A/L model and includes several multi-functional displays that present flight, navigation, and communication information to the aircrew. Jack was used to determine the level of anthropometric accommodation of small female aviators for reach and accessibility to all emergency and flight critical controls, and to identify any reach and visibility shortfalls for small female aviators in the crewstation. The goal was to establish the UH-60M accommodation cutoff for the U.S. Army female pilot population. Figure 15 shows a human figure model of a small female pilot seated in the UH-60M crewstation. This figure also shows the eye line for the aviator. In this example, the eye line collides with a portion of the dash, limiting the pilot field of view.

Figure 15. Model of a female pilot seated in the UH-60M crewstation.

Figure 16 shows an example of the field of view from the eye perspective for small female pilots at a 30-ft hover, with a large male figure 65 ft away. This analysis helped determine the field of view for small female pilots, and ensured that they could adequately view ground movement control (GMC) personnel.

The modeling results also showed that 11% of the female aviator population could not reach the emergency fire t-handle in the cockpit. Figure 17 shows the reach shortfall and a successful reach.

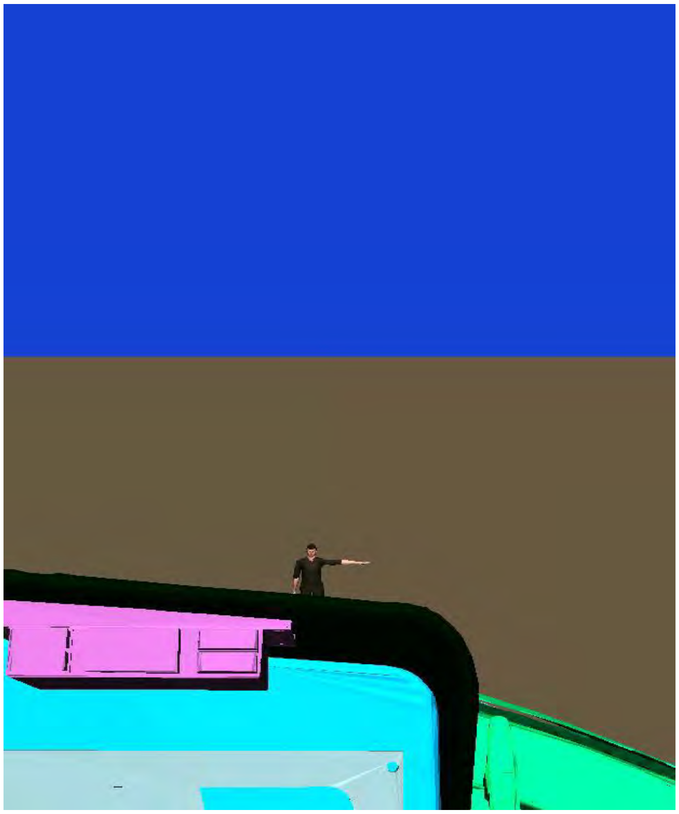

Figure 16. Field of view from the eye perspective of a small female pilot.

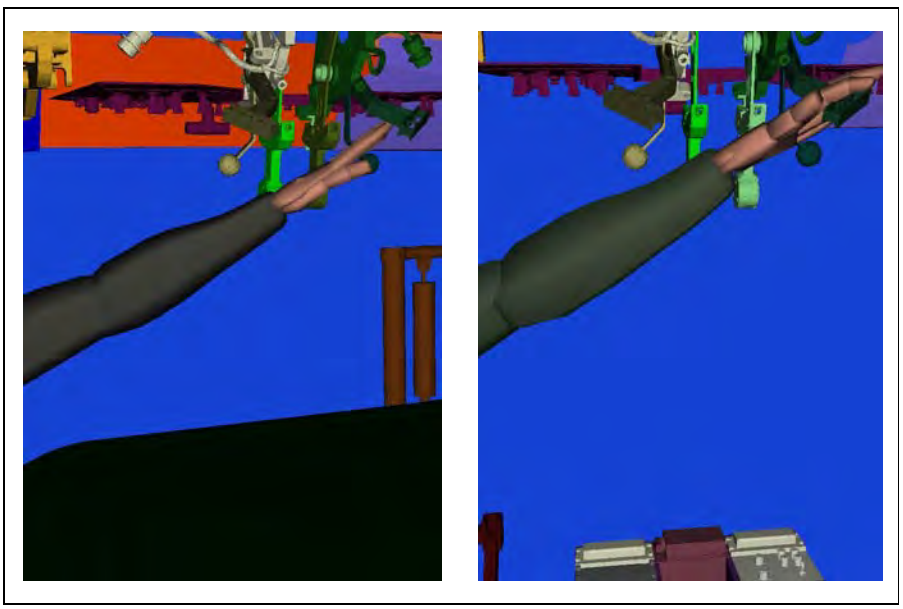

Figure 17. A reach shortfall and a successful reach.

The results of this analysis were briefed by ARL-HRED at the UH-60M critical design review (CDR); recommendations were made to improve over-the-nose vision for female and small male aviators and enhance access to the engine emergency fire T-handles for small female aviators (Kozycki, 2002). The recommendations were used to justify a smaller forward instrument panel in the crewstation and to improve external visibility (out of the crewstation) for small female aviators.

3.1.3 Army Airborne Command and Control System (A2C2S)

The A2C2S is a command and control system that is hosted inside of a UH-60 Blackhawk helicopter. The A2C2S consists of five seats with monitors and keyboards at each location. When the A2C2S system is manned and in use, there is restricted space inside the aircraft to perform egress procedures. An A2C2S emergency egress test was performed and documented by ARL-HRED, and analysis and test results were documented in a ARL-HRED technical report (Havir, Kozycki, 2005). Jack was used to complement the emergency egress test and provide recommendations. The purpose of the emergency egress testing was to verify current emergency egress procedures and improve the procedures, if necessary; specifically, the tests were performed on an aircraft with the A2C2S system installed to document problems that occur during egress from the aircraft, and to determine the optimal routes for exit. The egress tests were performed under several different scenarios, such as blocked exits and windows, and with personnel of different body sizes. The Jack analysis was used to make recommendations about egress routes and design changes that would improve safety and egress. Figure 18 shows a depiction of the UH-60 helicopter and the installed A2C2S system.

Figure 18. UH-60 helicopter with the A2C2S.

Jack illustrated (figure 19) that large males could potentially strike their heads against the upper left-hand corner of the flat screen monitor just before exiting the left cargo door opening.

Figure 19. Potential head strike during egress.

Participants in the front workstation positions were required to exit by either going over or under the workstation platforms, and then exiting out of the front of the aircraft. Figure 20 shows an operator attempting to egress by the crawlspace over the top of the console.

Figure 20. Large male figure attempting egress through the crawlspace over the top of the console.

Figure 21 shows a large male figure attempting to crawl underneath a workstation. This analysis identified the obstructions and difficulty that could occur while crawling through the crawl space and negotiating around the chair.

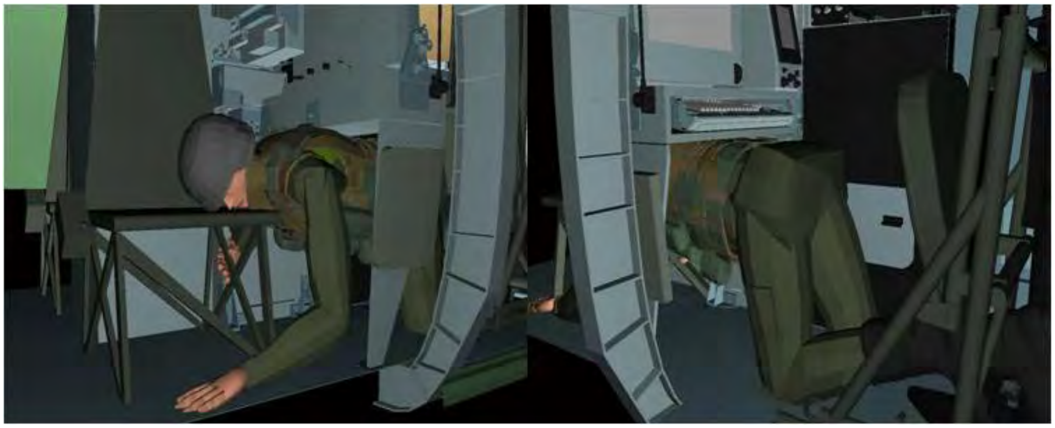

Figure 21. Large male figure attempting to crawl underneath a workstation.

Egress procedures from the front cargo doors were also conducted during this evaluation. Figure 22 shows the modeling screen shot that was used for analysis of this procedure.

Figure 22. Large male egressing through the cargo door window.

Jack provided graphical representation of improvements that could aid Soldiers during emergency egress. For example, headroom for tall males was identified as an egress hazard, as the space was relatively tight for taller Soldiers attempting to egress from the rear workstation positions. In order to remedy this problem, the monitor was rotated 20° back, in the model, to provide more head room. Figure 23 shows the improved space, where the A2C2S monitor is tilted at an angle of 20° to preclude inadvertent contact.

Figure 23. Additional head space provided by rotating the monitor.

Another recommendation as a result of the Jack analysis involved egress from either the front left or right workstation positions. Standard procedure was that the Soldier crawled over or under the workstation platform. Jack showed that if the workstation platform could be collapsed and folded down, the need to crawl over or under the platform could be eliminated. This design provided ample space for large male Soldiers to use it as an egress path, and it proved safer and quicker than having to climb over or crawl underneath the workstation. Figure 24 shows a large male figure attempting to egress through the space provided when the workstation was folded down.

Figure 24. Large male egressing through space provided when workstation is folded down.

The human figure modeling analysis identified and provided many of the same recommendations made by Soldiers during the actual A2C2S egress evaluation. This highlights the benefit and importance of conducting modeling and simulation early in the design stages of an acquisition program to identify and resolve issues.

3.1.4 Air Warrior

Air Warrior is an integrated ALSE system for Army aircrews. The ensemble can be tailored for specific missions and is designed to improve mission performance in the areas of aircraft interface, comfort, safety, and survivability. Figure 25 shows a digitized Air Warrior ensemble and figure 26 shows the ensemble placed on a human figure model.

ARL-HRED digitized the Air Warrior ensemble to enhance anthropometric assessments of Army Aviation systems. The digitized Air Warrior clothing and equipment provided modelers and analysts more realistic results when using the ensemble in aviation applications. The accuracy of the analysis greatly improves when the human figures are fitted with models of the same clothing and equipment that the actual aircrews wear. For example, if the human figure model in figure 27 was not attired in the Air Warrior ensemble, the analysis would indicate that the pilot had much more usable cockpit space than would be the case in the actual aircraft.

Figure 25. Digitized Air Warrior ensemble.

Figure 26. Digitized Air Warrior ensemble on a human figure model.

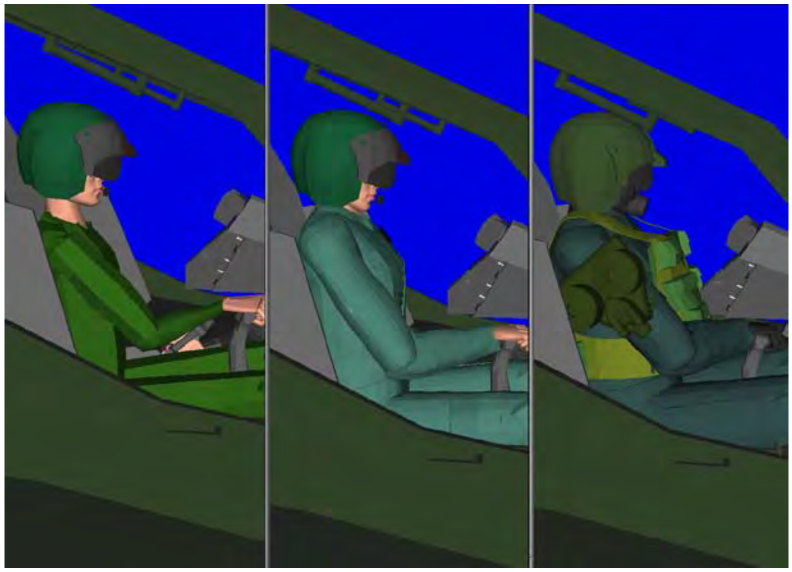

Figure 27. Human figure with different layers of clothing and equipment seated in an Apache cockpit.

To validate the use of the digitized Air Warrior ensemble during anthropometric analyses, a range of motion analysis was conducted. The analysis included a digitized human figure (attired in the Air Warrior ensemble) range of motion study, followed by a live subject range of motion study while the subject was wearing the Air Warrior ensemble. The analysis verified that the range of motion of the human figure model (attired in the Air Warrior ensemble) was very similar to the range of motion of an actual pilot when attired in the Air Warrior ensemble. Figures 28 and 29 show the digitized clothing scaled to different sizes and the comparison of the range of motion from the digitized equipment and the live test subject, respectively. The range of motion comparison showed that only slight differences occurred between the human figure-generated reach data (wireframe region) and the motion capture data (shaded area) from the live test subject. This analysis provided evidence that the digitized Air Warrior ensemble could be used on human figure models to provide an accurate representation of ALSE worn in the cockpit. The Air Warrior and range of motion analysis used for this summary can be reviewed in detail in the publication (Kozycki, 1998).

3.1.5 Common Missile Warning System (CMWS)

The Common Missile Warning System (CMWS) is a passive detection system used on Army Aviation systems to defeat infrared missiles. The CMWS sensors' field of view was modeled for an AH-64D Apache helicopter to compare the original sensor mounting location on the tail of the aircraft to the relocation of the sensor mounting to the stub wing of the aircraft. The comparison was conducted to determine if mounting the CMWS sensors on the stub wings would increase their field of view. In order for this comparison to take place, the Apache helicopter was digitized by ARL-HRED in two separate parts. The tail section was a detailed 3-D model

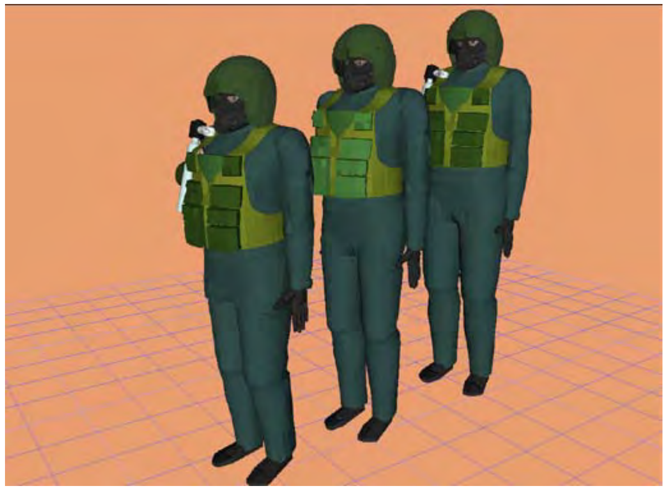

Figure 28. Different sizes of digitized clothing and models.

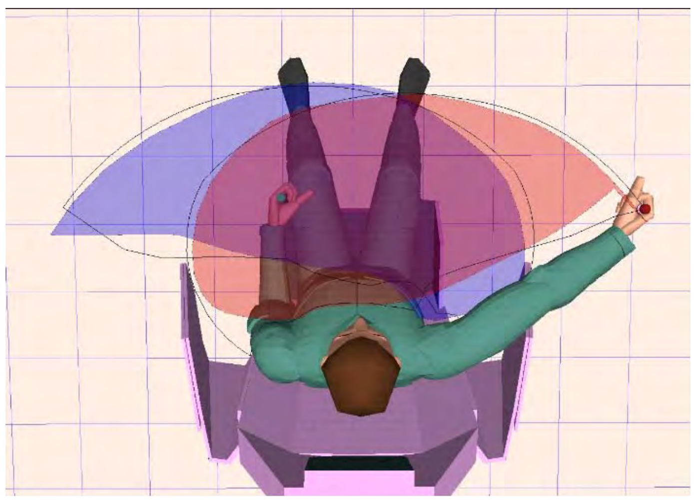

Figure 29. Range of motion comparison.

constructed using digitization, while the front section was a low-resolution commercially available model. Once the helicopter was digitized, field of view cones for the CMWS sensors were constructed in the modeling software. Figure 30 shows the field of view from the tail section of the aircraft where the CMWS rear sensors were originally located and the proposed improved sensor locations. The field of view from the original location was inhibited by the tail rotor and provided significantly less coverage than the location on the stub wing.

The modeling provided developers with information for optimal placement of the CMWS sensors. The results of this analysis were used to help justify a proposal that the CMWS sensors be moved to the stub wing locations to improve missile detection (Wittges, 2005). A design change was then implemented, and the sensors were moved to the stub wings.

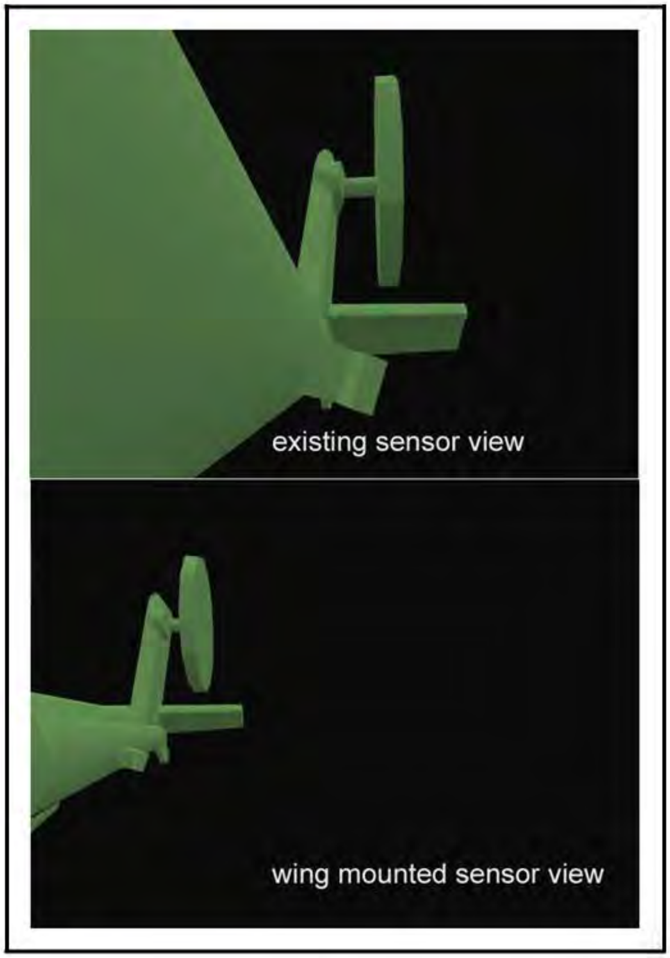

Figure 30. Field of view from the tail section and the stub wing locations.

3.1.6 Advanced Threat Infrared Countermeasure (ATIRCM)

The ATIRCM is a countermeasure system for aviation platforms that uses infrared jamming techniques to defeat infrared missile threats encountered during flight. A Jack modeling analysis was performed to assess the primary maintenance tasks for the ATIRCM Quick Reaction Capability (QRC) program in order to analyze potential maintainer interface problems and validate anthropometric requirements. The ATIRCM QRC system will be used on the CH-47 aircraft that are employed in Iraq and Afghanistan. The CH-47 and ATIRCM models were provided by the contractor (BAE systems) to ARL-HRED for the Jack analysis. The models were imported into Jack, and the analysis was conducted. Results of the Jack analysis were briefed by ARL-HRED personnel during the ATIRCM/CH-47D CDR.

One of the maintenance tasks identified as a concern (prior to the Jack analysis) was the removal of the optical coupler. Figure 31 shows a large male wearing cold weather clothing attempting to loosen the optical coupler, which connects the infrared jam head (IRJH) to the multi-band laser (MBL). The modeling results showed that a large male would be able to operate tools effectively in the available space to accomplish the task. Therefore, the need for further engineering analysis and a potential design change to the system was avoided.

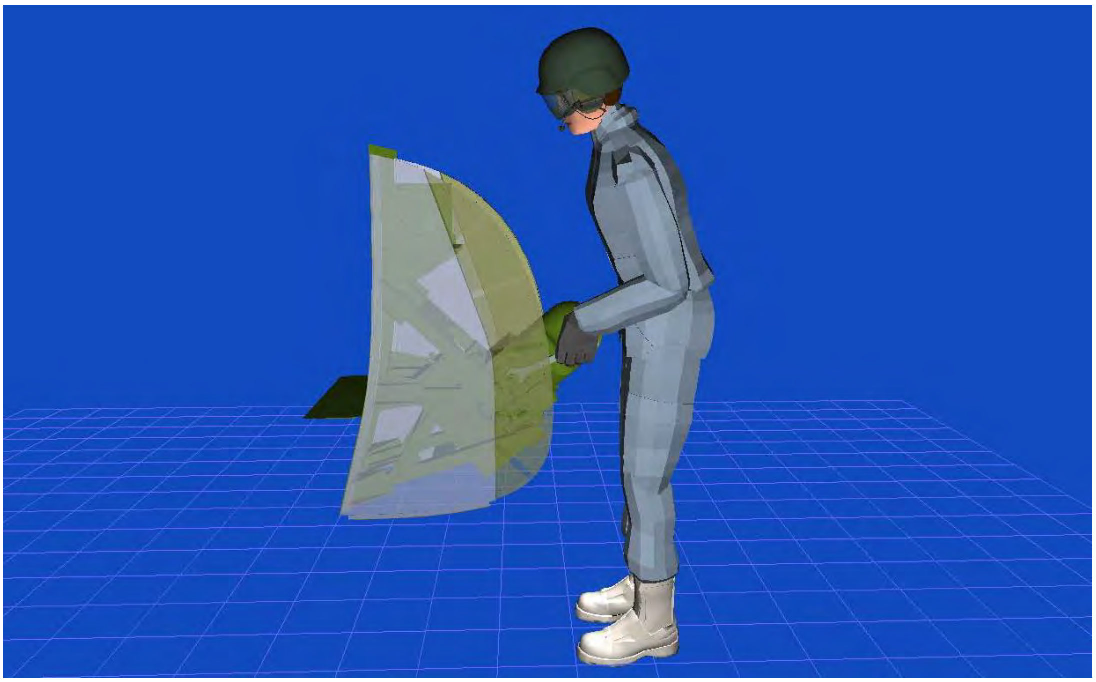

Figure 31. Large male loosening the optical coupler.

Another maintenance task that was identified as a concern was the removal/replacement of the jam head control unit (JHCU) by a small female. Figure 32 illustrates that a small female would have difficulty reaching the fasteners for the JHCU while the IRJH was installed. The recommendation for this task was to remove the IRJH prior to removal of the JHCU, as removing the IRJH provided improved access to the JHCU and minimized potential damage to the IRJH while conducting remove/replace tasks to the JHCU, as indicated in figure 33. The ATIRCM Technical Manual, “B-Kit Field Maintenance Manual,” was rewritten to incorporate the recommendation that was identified through the Jack analysis of removing the IRJH prior to removal of the JHCU.

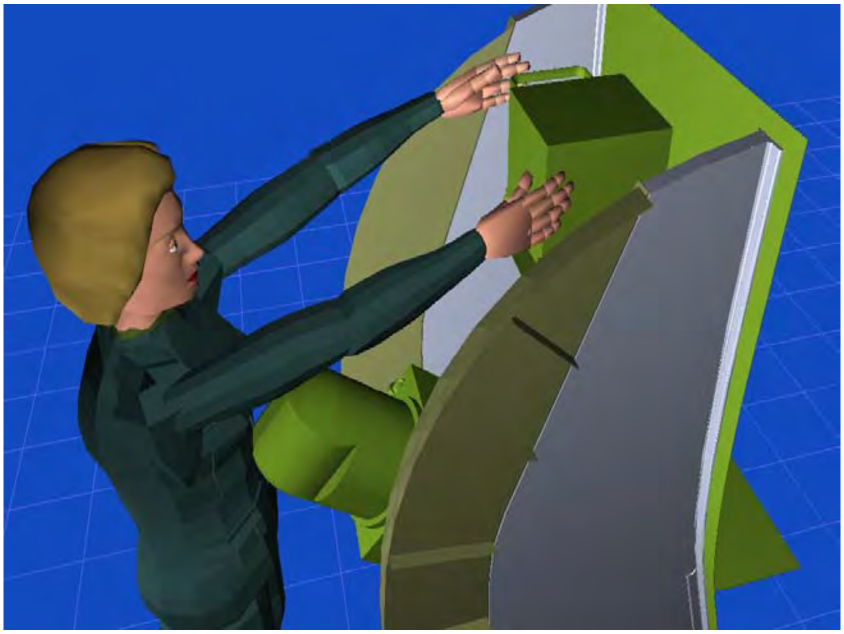

Figure 32. Small female having difficulty reaching the fasteners of the JHCU.

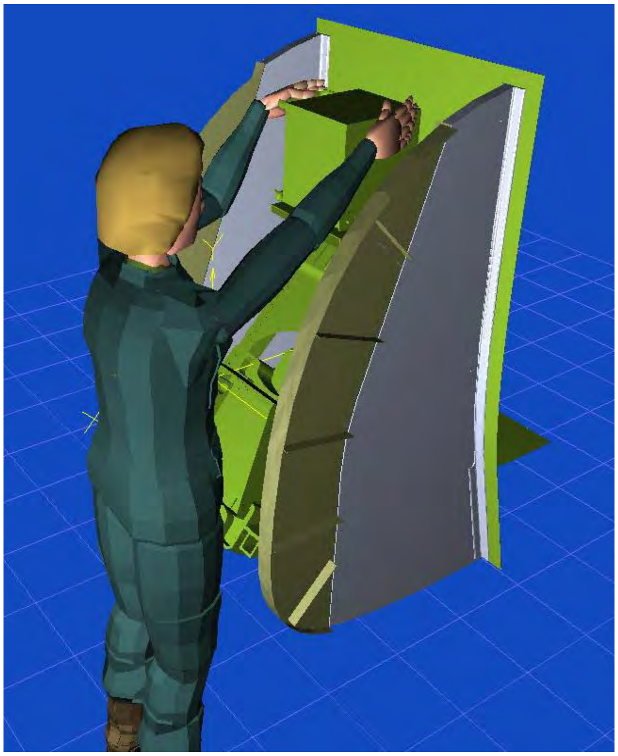

Figure 33. Small female reaching the JHCU after the removal of the IRJH.

3.1.7 Armed Reconnaissance Helicopter (ARH)

The ARH was a reconnaissance/scout helicopter designed to replace the OH-58D Kiowa Warrior. The ARH program was based on the Bell 407 commercial helicopter and was designed so that two ARH helicopters could be deployed aboard a C-130 cargo aircraft. A Jack analysis was performed for the Army Test and Evaluation Command to analyze whether two ARHs could be emplaced on a C-130, if there was sufficient volume of space for the pilots, crew chiefs, and loadmasters, and if there were suitable egress paths for personnel.

Figure 34 shows troops seated in the cargo area of the C-130, and figure 35 shows troops exiting the C-130 while attempting to avoid hazardous contact with the two ARH helicopters. The Jack analysis showed that two ARHs could, in fact, be emplaced in a C-130, and that there was sufficient volume of space for the pilots, crew chiefs, and loadmasters. It also determined that there were suitable egress paths for personnel. The results of this model were used to help conduct an emergency egress test with actual pilots, crew chiefs, and loadmasters (i.e., the Jack model results were used to assign seat locations for personnel and help them safely exit the C-130).

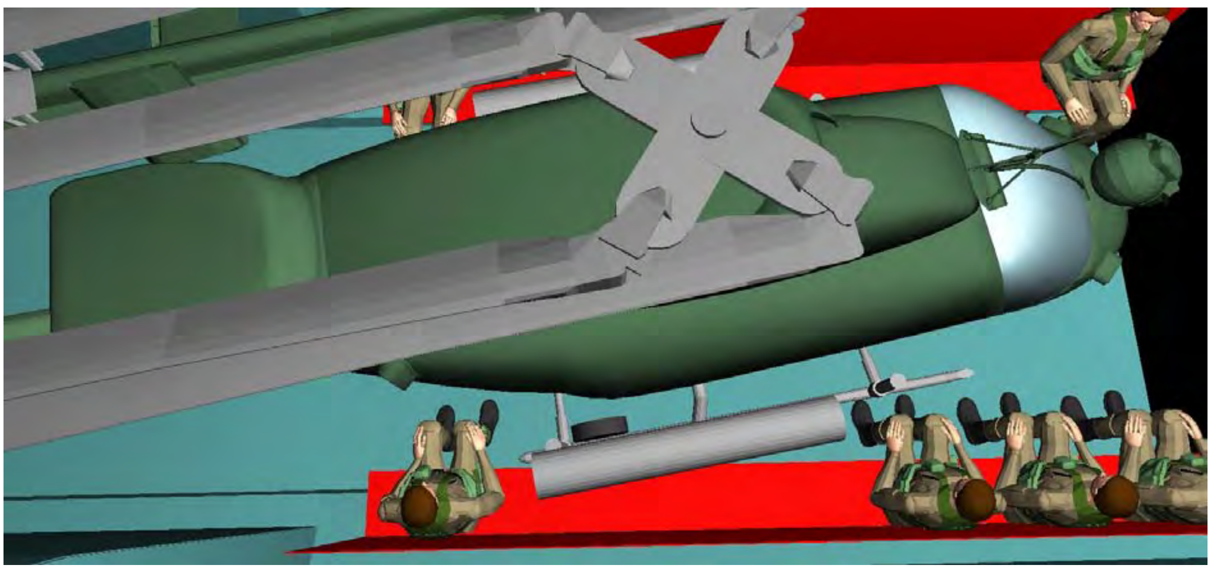

Figure 34. Troops seated in the cargo area of a C-130.

Figure 35. Troops exiting a C-130.

3.1.8 CH-47D Chinook

The Chinook is a heavy-lift helicopter used for troop, artillery, and supply transportation. ARL-HRED is currently conducting a human figure modeling assessment of the CH-47D Chinook to assess anthropometric requirements for pilots wearing the Air Warrior ensemble. ARL-HRED digitized the CH-47D helicopter at Fort Rucker, AL, using a coordinate measuring machine. The digitized helicopter model will be used to identify optimal locations in the CH-47D crewstation to stow pilot gear that is required to support operations in Southwest Asia, and to assess modifications to ALSE. Figure 36 shows a model of the CH-47D cockpit that will be used during the accommodation analysis. The digitized CH-47D will add to the library of aircraft models that ARL-HRED uses to assess and improve crewstation design, and enhance pilot performance.

Figure 36. Digital model of the CH-47D cockpit.

4. Conclusions

4.1 Human Figure Modeling for Army Aviation

ARL-HRED has used human figure modeling to develop and test Army Aviation systems. The modeling results have been used by government and industry to improve the ergonomic design and system functionality of the systems, assess anthropometric requirements, and reduce analysis timelines. Human figure modeling will continue to be used to develop and assess new and upgraded Aviation systems. This will include development of unmanned aircraft systems (UAS) and UAS ground control stations. Modeling will continue to play an increasingly important role in the future, as Army Aviation program managers work to reduce system design costs and shorten design, development, and production times.

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List of Symbols, Abbreviations, and Acronyms

3-D	Three-Dimensional
A2C2S	Army Airborne Command and Control System
ALSE	Aviation Life Support Equipment
AMRDEC	Aviation and Missile Research, Development and Engineering Center
ARH	Armed Reconnaissance Helicopter
ARL	U.S. Army Research Laboratory
ATEC	Army Test and Evaluation Command
ATIRCM	Advanced Threat Infrared Countermeasure System
CAD	Computer-Aided Design
CDR	Critical Design Review
CMM	Coordinate Measuring Machine
CMWS	Common Missile Warning System
ECL	Engine Control Lever
FOV	Field of View
GMC	Ground Movement Control
HFE	Human Factors Engineering
HGU	Headgear Unit
HIDSS	Helmet Integrated Display Sight System
HRED	Human Research and Engineering Directorate
HSI	Human System Integration
IRJH	Infrared Jam Head
JHCU	Jam Head Control Unit
M&S	Modeling and Simulation
MBL	Multi-band Laser

MFD	Multi-function Display
NBC	Nuclear, Biological, and Chemical
PCA	Principal Components Analysis
QRC	Quick Reaction Capability
SME	Subject Matter Expert
TRADOC	U.S. Army Training and Doctrine Command
TCM	TRADOC Capabilities Manager
UAS	Unmanned Aircraft System

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